Jet Propulsion Laboratory
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Landing on Europa: Challenges, Technologies, and Strategy

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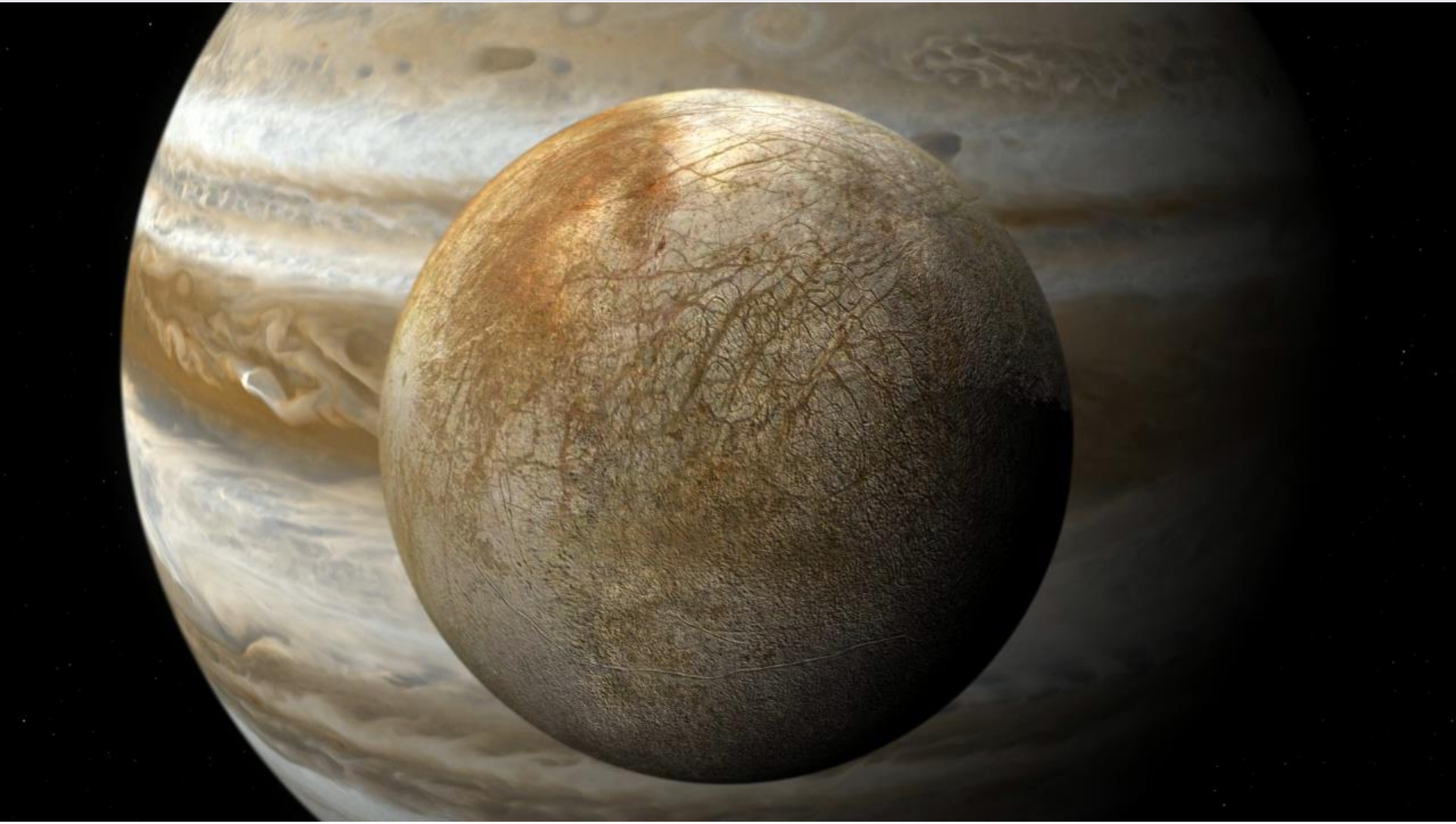
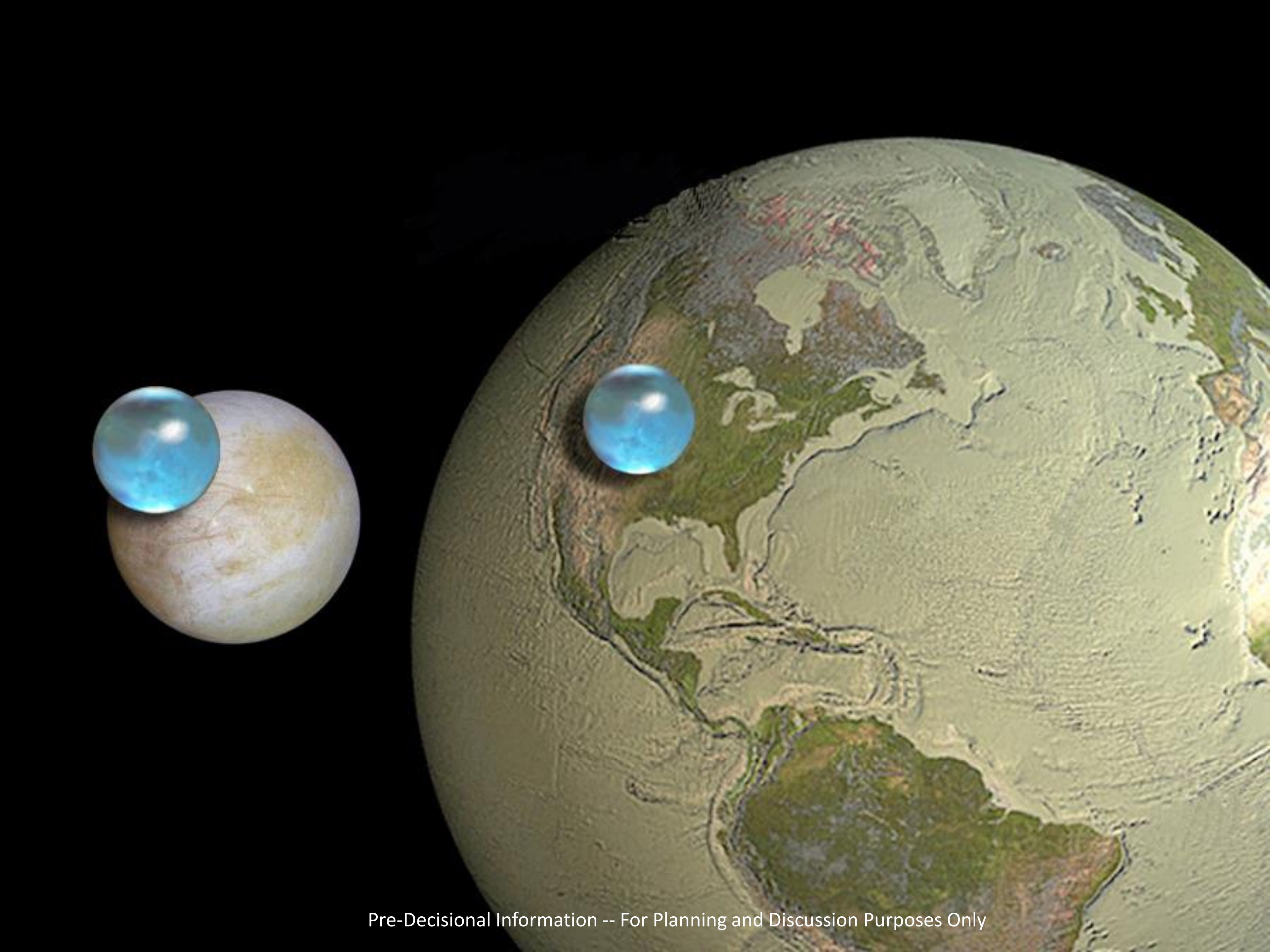
Why Explore Europa?





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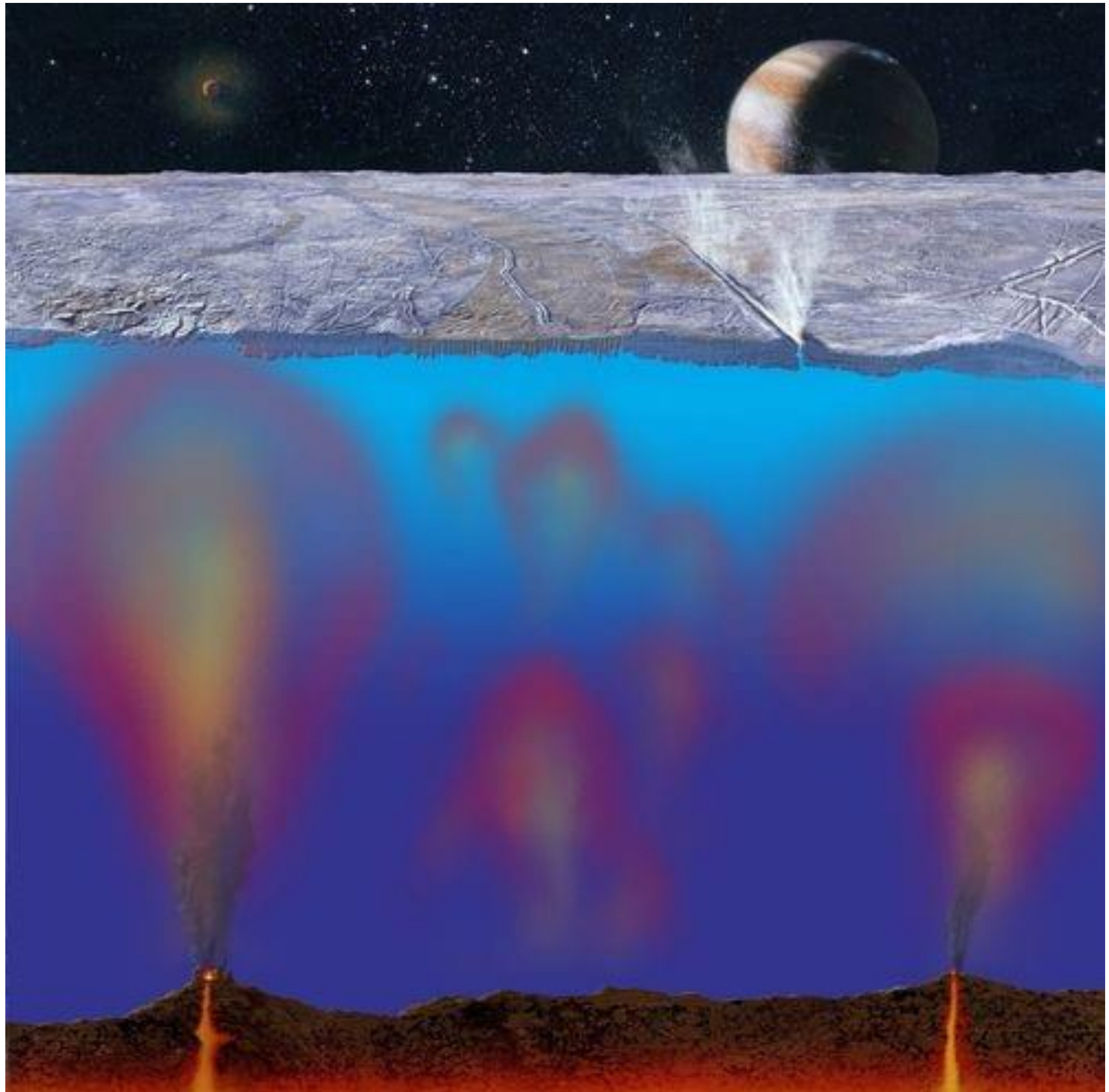


Mission Concept Goals

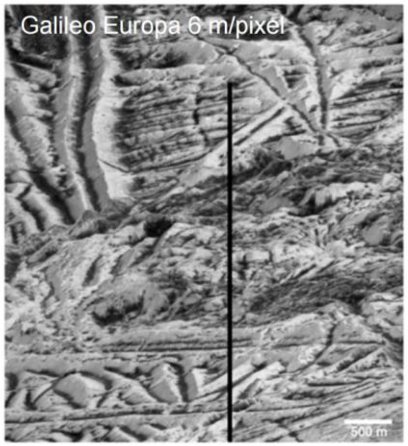
Assess the habitability of Europa via in-situ techniques uniquely available to a lander mission

Search for evidence of life on Europa

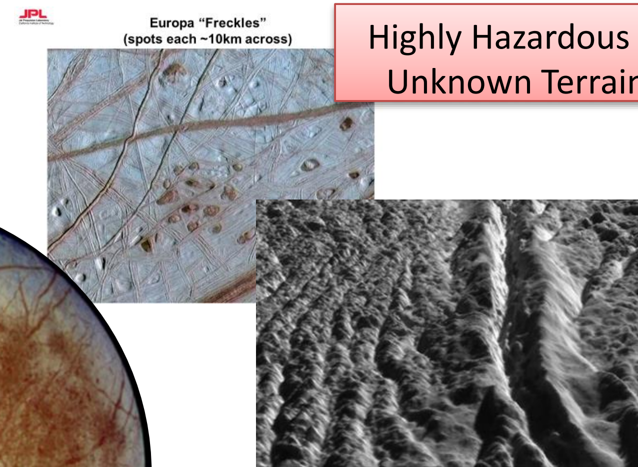
Characterize surface and subsurface properties at the scale of the lander to support future exploration

De-Orbit, Descent, and Landing (DDL) Challenges

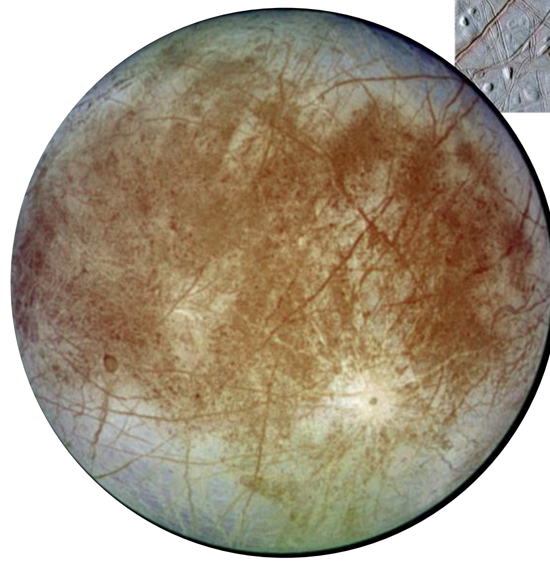
Current Lack of High-res Recon Maps



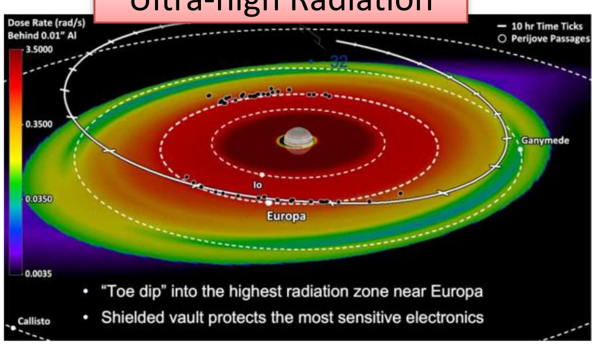
Highest Resolution Europa image currently available



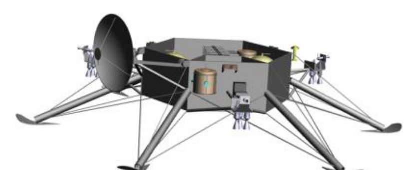
Highly Hazardous & Unknown Terrain



Ultra-high Radiation



Large Propulsive Delta-V



Artist's Concept

Limited Lander SWAP Resources

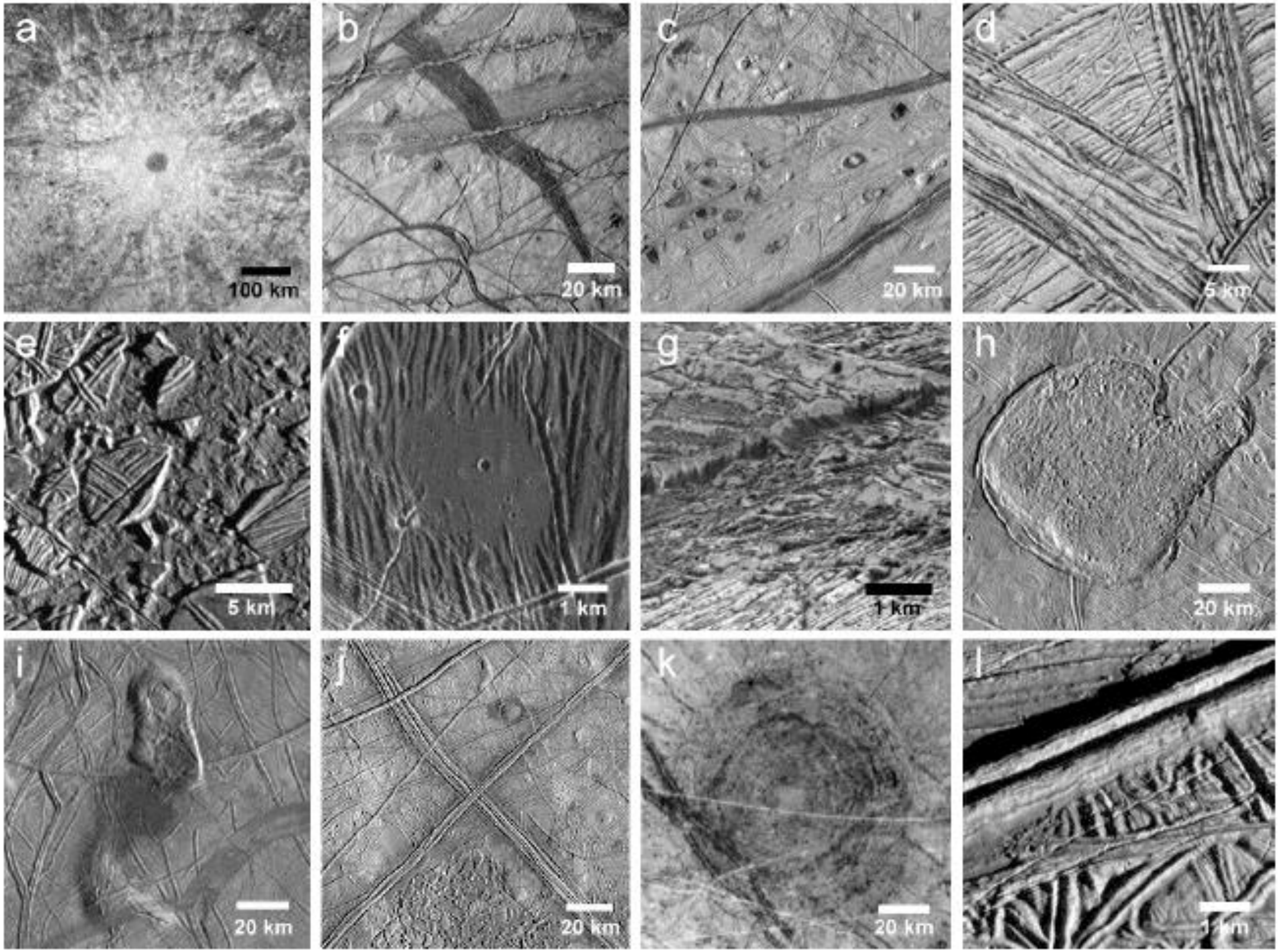
Terrain Uncertainty

- Little is known about the surface topography of Europa
  - 36% of surface imaged at 1 km/pxl
  - A few highly localized areas at 50 m/pxl

- Europa Lander concept would launch before we obtain any new information about Europa surface topography

Europa Lander concept must be robust to a wide variety of terrain types

Examples of Europa Terrain



Penitentes

Delivery Error

- Europa Lander would approach Europa at Start of DDL with a surface relative velocity of ~1950 m/s
- The Lander would be delivered to the start of the de-orbit burn with an along-track position error of about ±4500 m (3σ)
- The solid rocket motor errors would contribute as much as ±4 km (3σ) in along-track position error at de-orbit burn termination
- Collective opinion of the Europa scientific and engineering community is that it is unlikely that we will find a 9 km-long region on Europa that is scientifically interesting, accessible, and safe to land

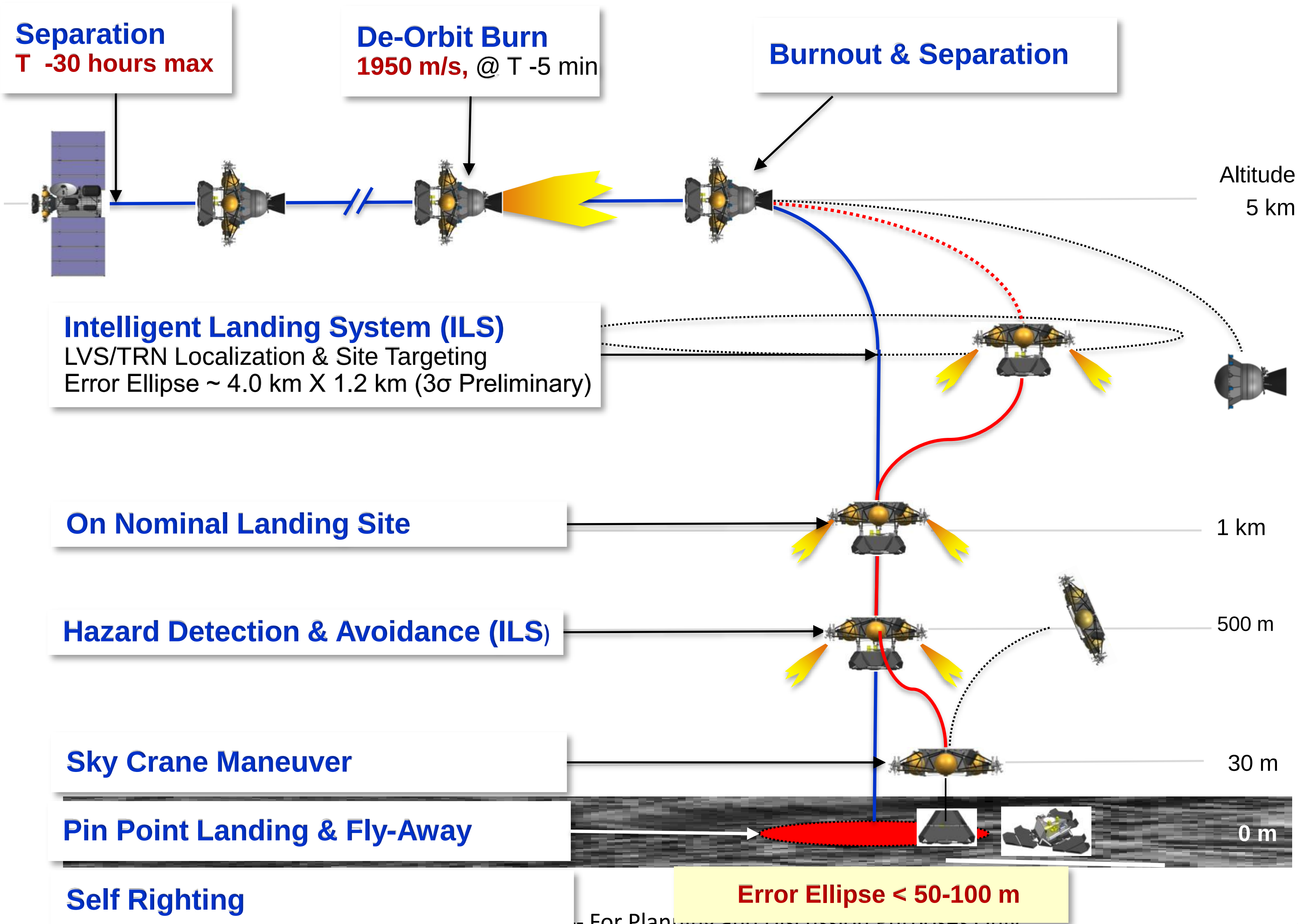
Radiation

- Jupiter’s magnetosphere traps and accelerates particles in a torus-like structure of radiation belts
  - Europa orbits Jupiter well within the high-radiation zone so radiation exposure to the Lander can only be minimized, not avoided
- Lander would be expected to experience a total ionizing dose (TID) of ~1.7 Mrad, primarily from electrons, behind 100 mil of aluminum
  - To attenuate the expected dose to 150 krad (Si), most electronics would be housed in a radiation vault
- Majority of the dose (both TID and displacement damage) would be accumulated in the end-phase of the mission
  - Long non-operational cruise duration coupled with the short and abrupt DDL phase implies that the time at which the best performance is required from the sensors and electronics coincides with the end-of-life or end-of-lander mission segment

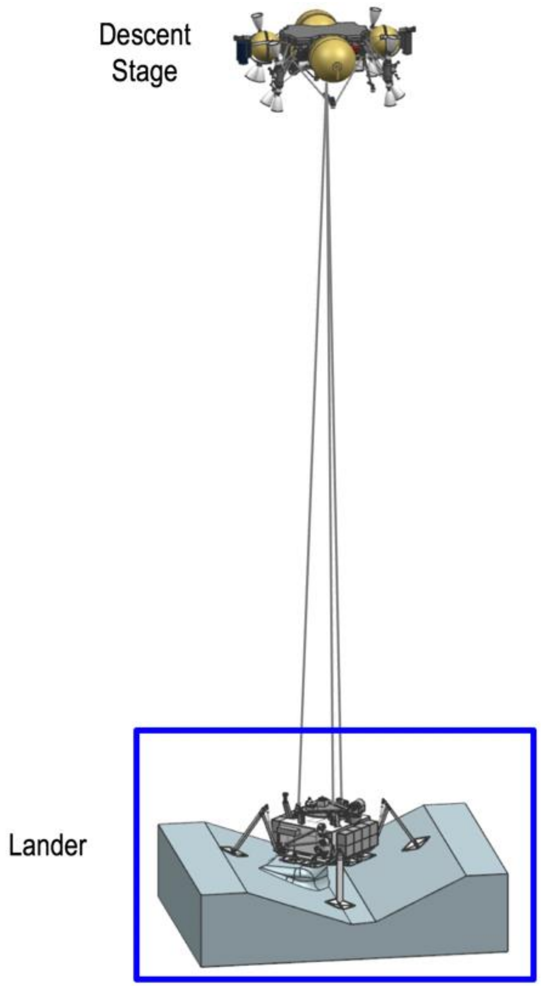
Planetary Protection

- Europa Lander must comply with Category IV NASA planetary protection requirements:
  - The probability of delivering to the surface of Europa a single viable terrestrial microorganism must be less than 10^{-4}
- This has great implications on the development, procurement, and processing of GN&C hardware element
- The project is evaluating a series of sterilization alternatives
  - Cleaning
  - Dry-heat microbial reduction (DHMR)
  - On-board incineration devices

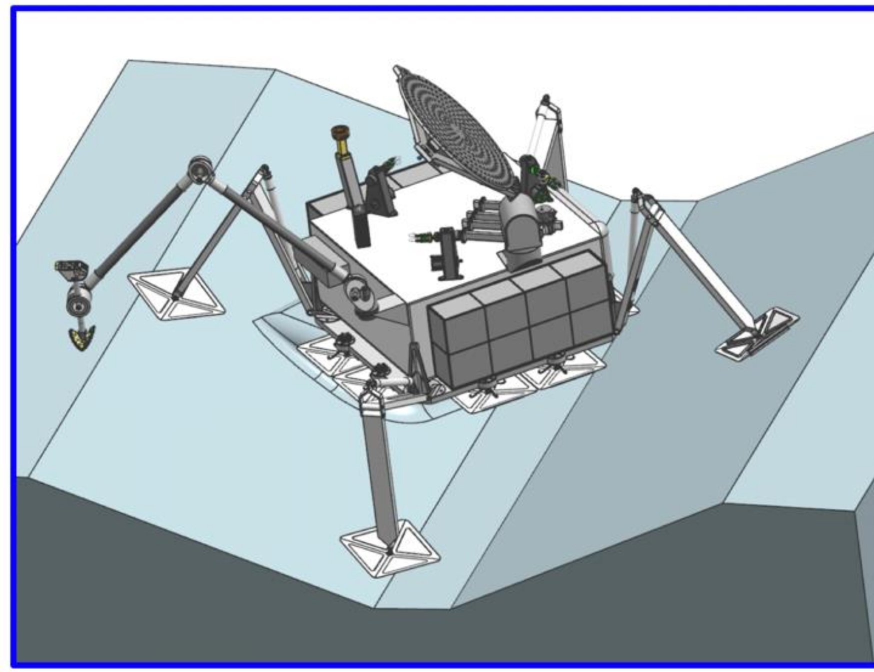
Precision Landing with TRN and HDA



SkyCrane with Landing Stabilizers

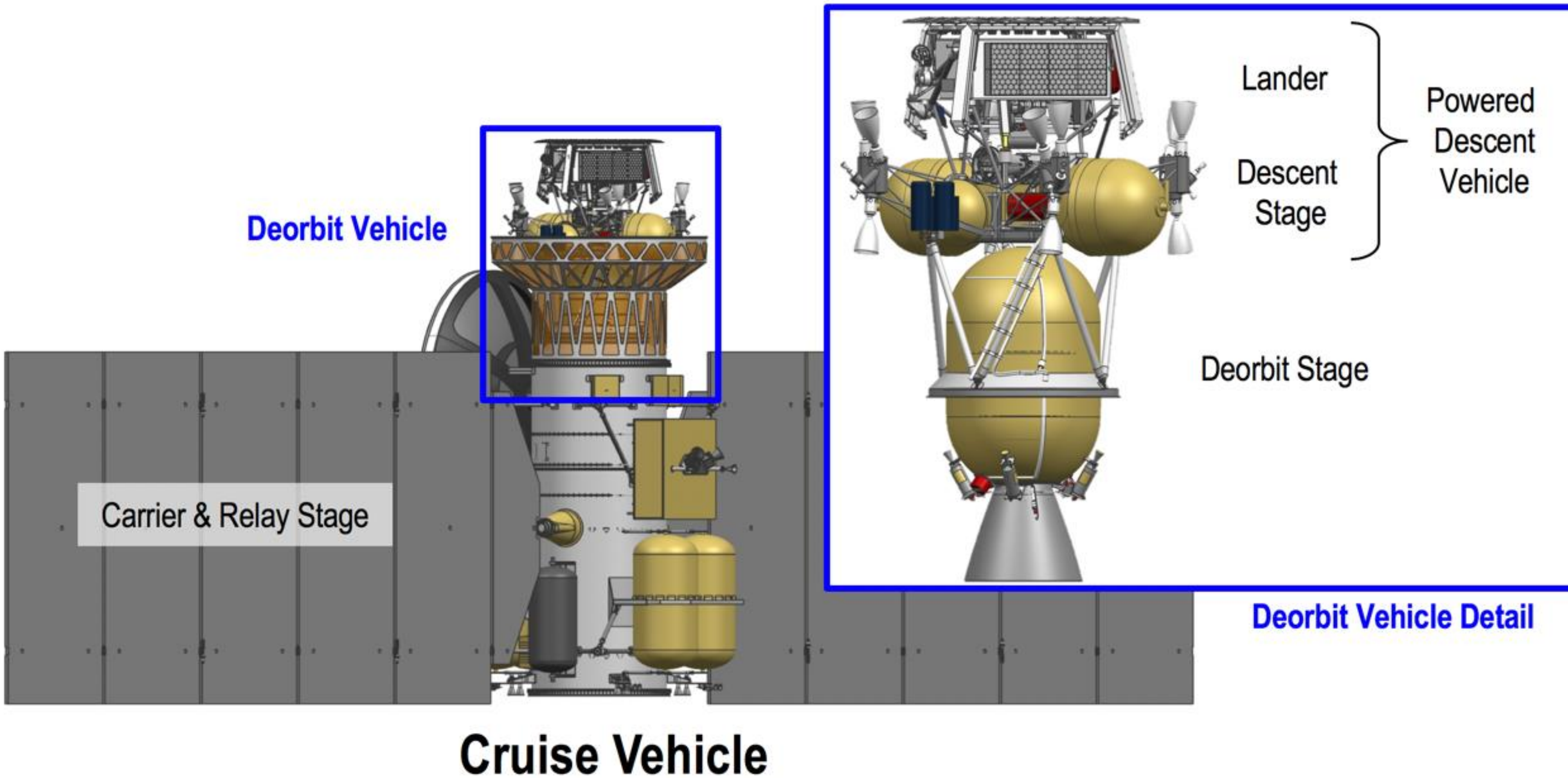


SkyCrane Delivery

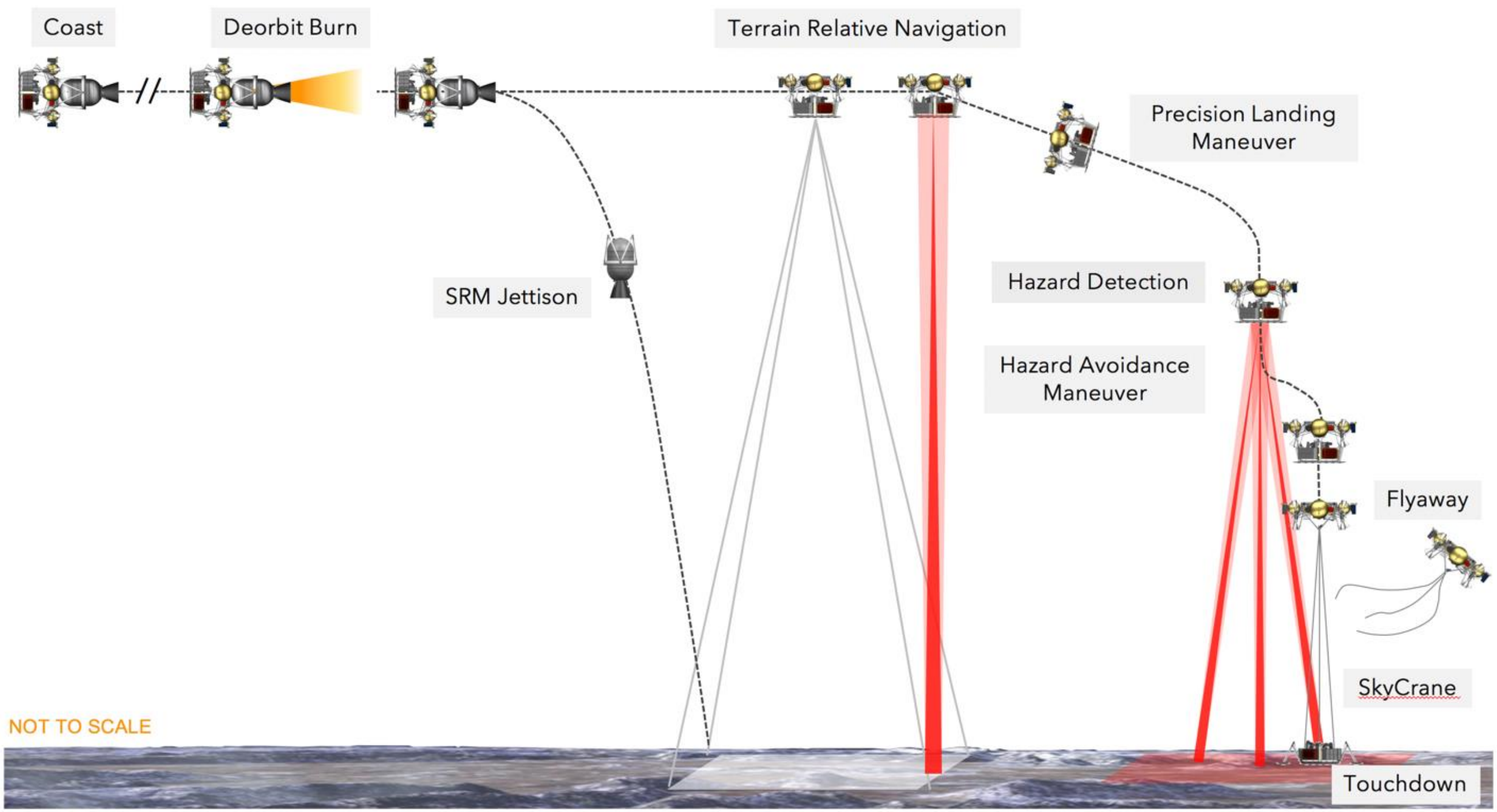


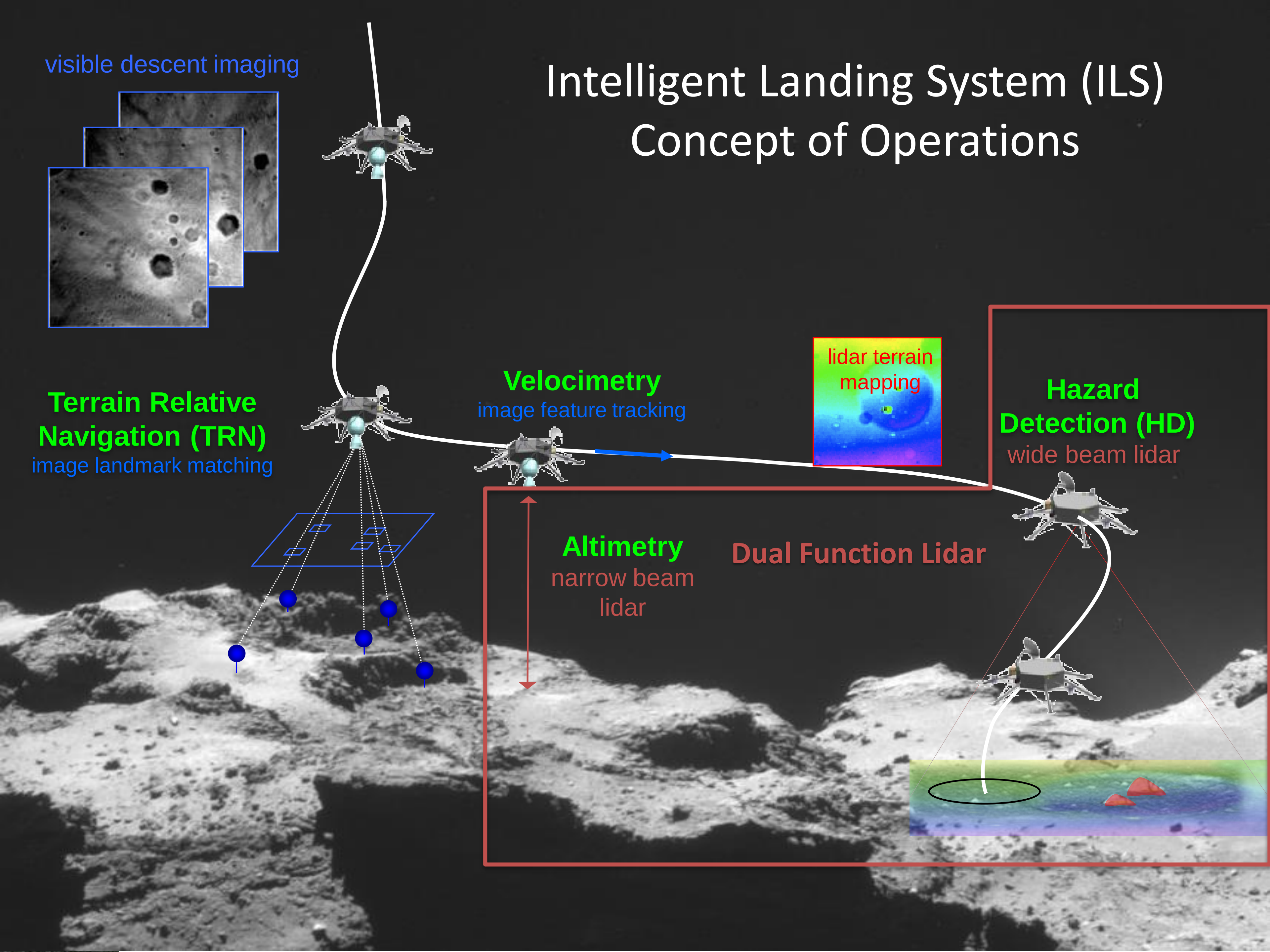
Lander Detail (Deployed Configuration)

Flight System Concept



DDL Strategy




Intelligent Landing System (ILS)
Concept of Operations
visible descent imaging
Terrain Relative Navigation (TRN)
image landmark matching
Velocimetry
image feature tracking
lidar terrain mapping
Hazard Detection (HD)
wide beam lidar
Altimetry
narrow beam lidar
Dual Function Lidar

Summary

- Europa is a very important science target for the study of astrobiology, and a mission to its surface would provide the greatest insight on this subject
- Landing on Europa presents a series of difficult challenges, the main being uncertain terrain and the radiation environment
- A DDL and GN&C architecture has been developed that addresses these challenges by implementing the following technologies
  - Precision Landing enabled by Terrain Relative Navigation
  - Hazard Detection and Avoidance based on 3D-LIDAR
  - SkyCrane and Landing Stabilizers for touchdown